5.0 WATER QUALITY AND CROSS-MEDIA IMPACTS

5.1 Impaired Water Bodies

Prior to the early 1970s, the following U.S. rivers were among those highly polluted by discharges from major iron and steel mills:

- Cuyahoga River at Cleveland, Ohio;
- Grand Calumet River at Gary, Indiana;
- Indiana Harbor Ship Canal at East Chicago, Indiana;
- Mahoning River at Warren and Youngstown, Ohio;
- Monongahela River in Western Pennsylvania;
- Black River at Lorain, Ohio;
- Rouge River at Dearborn, Michigan; and
- Ohio River at Weirton, WV and Steubenville, Ohio.

At that time, many of these streams were polluted with heavy floating oils from untreated and partially treated discharges from rolling mills; low pH and high iron levels from dumping of spent pickling acids and untreated pickling rinse waters; and high concentrations of ammonia-N, cyanide and phenols (4AAP) discharged from coke plants and blast furnaces. These conditions greatly improved during the 1970s and early 1980s through implementation of the first technology-based NPDES permits and federal and state enforcement actions.

Despite major improvements in these and other steel mill streams, state agencies have identified 40 iron and steel mills with discharges to impaired water bodies. (See Appendix C, Iron and Steel Manufacturing Facilities Included on State 304(l) Short Lists). Most facilities were listed because of toxic metal discharges. Other pollutants listed include cyanide, phenols (4AAP), selected toxic organic pollutants, and whole effluent toxicity (WET).[64] This is an indication that the current Part 420 is not wholly adequate to protect receiving water quality.

Current NPDES permits for most integrated steel mills contain a combination of technology-based effluent limitations and water quality-based effluent limitations (WQBELs). Mills such as the U.S. Steel - Gary Works, Inland Steel - Indiana Harbor Works and the Bethlehem Steel - Burns Harbor Division have internal monitoring stations where technology-based effluent limitations apply and outfalls where combinations of technology-based effluent limitations and WQBELS apply. Since the current Part 420 was promulgated, many state water quality standards have been upgraded to include more stringent chemical-specific criteria for toxic metals, ammonia-N and cyanide to conform to U.S. EPA water quality criteria. This has resulted in application of WQBELs more stringent than corresponding technology-based effluent limitations. It is more likely that mills located on large receiving streams will be limited more so by the current Part 420 than WQBELs, while mills located on small receiving streams will principally be limited by WQBELs.

5.2 Receiving Water Sediments

There are several documented cases of receiving water sediment contamination caused by historical discharges from iron and steel mills:

Receiving Water	Iron and Steel Mill
Black River at Lorain, OH	USX/Kobe Steel
Grand Calumet River at Gary, IN	U.S. Steel - Gary Works
Indiana Harbor Ship Canal	Inland Steel, LTV Steel
Mahoning River	LTV Steel
Black Creek at Gadsden, AL	Gulf States Steel

Sediments in the Black River at Lorain, Ohio were contaminated by discharges of PAHs from cokemaking operations. These sediments have been partially remediated under the terms of a consent agreement between U.S. Steel and EPA.[65] As required by a federal consent order, U.S. Steel has characterized contaminated sediments in the Grand Calumet River,[66] and is currently negotiating the terms and extent of a major sediment remediation program with EPA.[67] Also as part

of a federal consent order, Inland Steel has committed to a sediment characterization and remediation program for part of the Indiana Harbor Ship Canal and Indiana Harbor.[68]

During the mid-1980s, EPA Region 5 conducted sediment screening studies in receiving streams for a number of current (at the time) and former coke manufacturing sites and documented sediment contamination by PAHs.[69] The results of these studies suggest a high probability that sediments contaminated by PAHs can be found at and immediately downstream of most active and inactive coke plants located in the U.S.

5.3 Groundwater

Groundwater pollution at integrated iron and steel mills has resulted from: leaking wastewater collection sumps, leaking coke quench towers, and leaking blast furnace slag pits; leaking wastewater treatment lagoons and ponds; historical direct disposal of spent pickling acids in earthen pits; and leaking underground storage tanks and pipelines used to store and transport fuel oils and various chemicals including chlorinated solvents.

It is likely that many active and former by-product cokemaking sites have groundwater contamination. Disposal of untreated waste ammonia liquor and by-product recovery wastewaters by coke quenching was a common practice at many coke plants prior to and during the 1960s and 1970s. This method of wastewater disposal is still practiced at a few active coke plants. Groundwater contamination resulted from leaking coke quench pits used to collect and recycle excess quench water. These pits are usually constructed of concrete and remain in service as long as the coke batteries are operated, generally from 20 to more than 40 years. Other coke plant groundwater contamination sources include leaking by-product recovery wastewater collection sumps, disposal of tank drag-outs and process wastes in unlined surface impoundments, and leaking storage tanks. Principal pollutants include benzene, toluene, xylene, ammonia, cyanide, phenolics, and PAHs.

Similarly, disposal of blast furnace gas wash recycle system blowdown by evaporation on blast furnace slag has caused groundwater contamination at a number of mills from leaking slag pits and inadequate containment of excess quench water. Groundwater contamination from this source is a relatively recent phenomena compared to contamination from leaking coke quench pits. Most blast furnaces were equipped with treatment and recycle systems during the 1970s, and disposal of recycle system blowdown did not become widespread until the early and mid-1980s when compliance with Part 420 became an issue for blast furnace operators. Disposal of recycle system blowdowns by slag quenching offered a relatively low-cost means to comply with Part 420. Groundwater contamination from blast furnace operations is characterized by ammonia, cyanide, and phenolics.

Many other sources of groundwater contamination at steel mills are similar to those found at other industrial manufacturing sites: leaking above-ground and below-ground fuel storage tanks and leaking underground storage tanks of chlorinated solvents (e.g., trichloroethylene, tetrachloroethylene).

5.4 Air

Most of the cross-media impacts in the iron and steel industry involve pollutant transfers from air to water and solid waste media from wet and semi-wet air pollution control systems and from blast furnace and coke oven gas cleaning systems. Disposal of untreated coke plant waste ammonia liquor and by-product recovery wastewaters by coke quenching probably causes the greatest transfer of pollutants from water to air; however, this practice is currently limited to a relatively small number of plants. Other water-to-air transfers result from loss of volatile pollutants from: open coke plant wastewater equalization and storage tanks and wastewater treatment systems; open process wastewater sumps; emissions from blast furnace slag pits where blast furnace blowdown is used for slag quenching; and volatilization of oil-based compounds from hot forming and cold rolling wastewater treatment systems. When Part 420 was promulgated, EPA found that the effluent reduction benefits associated with disposal of blast furnace blowdown by slag quenching outweighed the air pollution impacts.[13]

5.5 Solid and Hazardous Waste

As noted above, most of the cross-media impacts in the iron and steel industry involve transfers of air emissions to water through wet and semi-wet air pollution control systems and subsequent transfers from wastewater to solid waste in the form of wastewater treatment sludge. There are also direct transfers from air to solid waste from dry air pollution control systems, the most prominent of which are dry air controls on EAFs.

There are also opportunities for transfers from solid waste to water from handling and disposal of wastewater sludges and air pollution control dust. At some mills, runoff from dewatered wastewater sludge collection and storage areas reaches noncontact cooling water and stormwater discharges without treatment. At other mills, air pollution control dust falls to the ground to be absorbed in subsequent runoff in stormwater and noncontact cooling water discharges.

5.6 Opportunities for Multimedia Rulemaking

Because many of the wastewaters generated from basic steelmaking operations result from air emission control or gas cleaning operations, there are obvious opportunities for multimedia rulemaking. To the extent that dry air controls can be the basis for either the air or water technology-based emission or discharge limitations, wastewater discharges can be eliminated. This can be done within the water media alone by setting NSPS at zero discharge for those operations where dry air controls are a viable technology (e.g., sinter plants, EAFs, ladle metallurgy stations, scarfers on hot forming mills, all of which are demonstrated in the industry). A coordinated review of all iron and steel industry operations may yield additional opportunities.

Coke quenching operations are limited by State Implementation Plans (SIPs) for particulate emissions only. Many of these limitations are in the form of maximum allowable total dissolved solids (TDS) concentrations in quench water. Pollutants characteristic of coke plant and by-product recovery wastewaters (ammonia-N, cyanide, phenols (4AAP), benzene, toluene, xylene and PAHs) are not regulated. Because of the benzene NESHAP regulations currently applicable to coke plants and additional pending regulations for HAPs (hazardous air pollutants) under the Clean Air Act, a coordinated air/water review of coke plant regulations would ensure that the resulting regulations would not be contradictory.

Other opportunities for multimedia rulemaking include consideration of regulations that would limit disposal of iron and steel industry wastewaters by non-discharge methods such as slag quenching and incineration in steelmaking furnace air emission control systems. Coordinated rulemaking could also be considered to control groundwater contamination resulting from wastewater treatment and disposal.

5.7 Review of Recent Permit Violations and Enforcement Actions

5.7.1 Recent Permit Violations

Tables 5-1 through 5-6 summarize data from EPA's Permit Compliance System (PCS) Database regarding documented NPDES permit violations. The data for 1994 are only complete through August 31, 1994. For each parameter, the number of violations and the number of companies representing the violations are presented.

5.7.2 Recent Federal and State Clean Water Act Enforcement Cases

During the past six years, at least four major federal enforcement cases and one major state enforcement case have been brought against iron and steel manufacturers for NPDES permit violations under the Clean Water Act. The four federal enforcement actions were eventually settled through negotiations resulting in Consent Agreements or Consent Orders, whereby the affected

companies agreed to technical remedies, and cash penalties and stipulated penalties for continuing violations. The one state action has not been completed at this writing. Following is a brief summary of each case describing the types of NPDES permit violations alleged, the technical remedies and the cash penalties.

U.S.A. v. USX Corporation (Civil Action No. 88-558, N.D. Indiana)

In 1988, the U.S. Government alleged that U.S. Steel's integrated mill at Gary, Indiana made unauthorized discharges of blast furnace process wastewater from noncontact cooling water outfalls, exceeded NPDES permit effluent limitations for ironmaking and steel finishing operations, made unauthorized discharges of intake screen backwash, and made unauthorized discharges from unpermitted outfalls.

The Consent Order issued in 1990 required U.S. Steel to pay a cash penalty of $1.6 million; spend at least $7.5 million for receiving stream sediment characterization and remediation; and make several process wastewater sewer rehabilitation and treatment system upgrades, which were reported to cost about $26 million. These upgrades included: installation of a recycle system for basic oxygen process contact gas cooling water; development and implementation of a coke plant wastewater management plan; rehabilitation of coke plant cooling water sewers; corrections for discharges of blast furnace gas seal overflows and blast furnace process water cross-connections to noncontact cooling water outfalls; routing of finishing mill basement sump discharges to the finishing mills treatment system; and development and implementation of a visible oil monitoring and correction action program for process and cooling water outfalls discharging to the Grand Calumet River.

U.S.A. v. Wheeling-Pittsburgh Steel Corporation (Civil Action No. C-2-88-598, S.D., Ohio)

In 1988, the U.S. Government brought a civil action against Wheeling-Pittsburgh Steel for its plants located at Steubenville, Mingo Junction and Yorkville, Ohio (the Steubenville-North, Steubenville-South and Yorkville Plants) for exceedances of NPDES permit effluent limitations and untimely installation of wastewater treatment facilities necessary to comply with the technology-based BPT and BAT effluent limitations applicable to those facilities.

The Consent Order for this case was issued in 1991 and required Wheeling-Pittsburgh to pay a cash penalty of $6.1 million, complete construction of process wastewater treatment facilities that was underway at the time of the lawsuit, and conduct a series of investigative and corrective action programs at each facility, many of which were similar to those required by the U.S. Steel Consent Decree noted above.

U.S.A. v. Wheeling-Pittsburgh Steel Corporation (Civil Action No. 89-2375, W.D., PA)

The U.S. Government also brought suit against Wheeling-Pittsburgh Steel for NPDES permit violations at its Allenport, Pennsylvania steel finishing plant in 1989. The Consent Order in that case was issued in 1992 and required Wheeling-Pittsburgh Steel to pay a cash penalty of about $2 million and upgrade the process water and process wastewater treatment systems at the mill.

U.S.A. v. Inland Steel Corporation (Civil Action No. H90-038, N.D. Indiana)

The U.S. Government's case against Inland Steel involved Resource Conservation and Recovery Act, Clean Air Act, and NPDES permit effluent violations. The Consent Decree in that

case required Inland Steel to pay a cash penalty of $3.5 million for all media violations. The case was filed in October 1990 and the Consent Decree was issued in March 1993.

The required wastewater remedial actions included: upgrading sampling and analytical quality assurance/quality control programs; a heavy metal corrosion inhibitor control program; investigations and corrective actions at a number of process and cooling water outfalls; rehabilitation of a sanitary wastewater treatment plant; development of a plant-wide environmental communications program directed at spill prevention, control and response; and a plant-wide visible oil monitoring and corrective action program. Inland Steel also agreed to conduct sediment characterization and remediation in Indiana Harbor and the Indiana Harbor Ship Canal as a supplemental environmental project.

IDEM v. LTV Steel Company, Inc. (Indiana Cause No. 37C01-9104-CP-54)

The Indiana Department of Environmental Management filed a civil enforcement case against LTV Steel in 1991 for NPDES permit effluent violations from sintering, ironmaking, steelmaking, vacuum degassing, and continuous casting operations at the LTV Steel Indiana Harbor Works located in East Chicago, Indiana. The complaint also alleged that LTV Steel caused an oil spill to the Indiana Harbor Ship Canal. The case is pending at this writing.

Table 5-1

EPA Permit Compliance System Violations (1989)

Parameter	Number of Violations	Number of Companies
Dissolved oxygen (DO)	16	7
BOD, 5-day (20 deg. C)	30	15
Chemical oxygen demand (COD)	6	3
pH	282	61
Total suspended solids	266	60
Oil and grease	157	39
Nitrogen, Ammonia Total (as N)	68	16
Total phosphorous (as P)	7	2
Total organic carbon	3	1
Total cyanide	28	12
Free cyanide (amen. to chlorination)	10	3
Total arsenic	3	1
Total cadmium	4	1
Hexavalent chromium	17	7
Total chromium	24	13
Total cobalt	1	1
Total copper	7	6
Total iron	98	14
Dissolved iron	5	1
Total lead	52	20
Total manganese	9	3
Total nickel	24	6
Total silver	1	1
Total zinc	130	32

Table 5-1 (Continued)

EPA Permit Compliance System Violations (1989)

Parameter	Number of Violations	Number of Companies
Total aluminum	4	1
Total recoverable phenolics	49	11
Toluene	2	1
Benzene	6	3
Benzo(a)pyrene	11	2
1,1,1-trichloroethane	9	1
Phenol, single compound	15	2
Naphthalene	25	5
Phenols	1	1

Table 5-2

EPA Permit Compliance System Violations (1990)

Parameter	Number of Violations	Number of Companies
Dissolved oxygen (DO)	10	5
BOD, 5-day (20 deg. C)	13	10
Chemical oxygen demand (COD)	6	2
pH	313	60
Total suspended solids	323	73
Oil and grease	166	47
Nitrogen, Ammonia Total (as N)	89	20
Total phosphorous (as P)	7	3
Total organic carbon	10	2
Total cyanide	39	15
Free cyanide (amen. to chlorination)	9	7
Total cadmium	1	1
Hexavalent chromium	19	7
Total chromium	23	10
Total copper	28	7
Total iron	97	15
Total lead	64	17
Total manganese	7	3
Total thallium	6	1
Total nickel	29	9
Total silver	1	1
Total zinc	171	46
Total antimony	1	1
Total aluminum	2	1

Table 5-2 (Continued)

EPA Permit Compliance System Violations (1990)

Parameter	Number of Violations	Number of Companies
Total recoverable phenolics	52	12
Toluene	1	1
Benzene	4	2
Benzo(a)pyrene	3	2
Fluorene	1	1
1,1,1-trichloroethane	3	1
Phenol, single compound	2	2
Naphthalene	29	9
Phenols	2	2

Table 5-3

EPA Permit Compliance System Violations (1991)

Parameter	Number of Violations	Number of Companies
Dissolved oxygen (DO)	19	9
BOD, 5-day (20 deg. C)	19	10
Chemical oxygen demand (COD)	3	2
pH	309	75
Total suspended solids	258	70
Oil and grease	185	46
Nitrogen, Ammonia Total (as N)	68	23
Total organic carbon	2	2
Total cyanide	46	12
Free cyanide (amen. to chlorination)	11	2
Hexavalent chromium	23	8
Total chromium	19	10
Total copper	17	7
Total iron	73	12
Dissolved iron	4	2
Total lead	47	15
Total manganese	2	2
Total thallium	12	1
Total nickel	22	9
Total silver	5	2
Total zinc	138	36
Total antimony	1	1
Total aluminum	2	1
Total recoverable phenolics	55	9

Table 5-3 (Continued)

EPA Permit Compliance System Violations (1991)

Parameter	Number of Violations	Number of Companies
Benzene	1	1
Benzo(a)pyrene	1	1
Fluoranthene	1	1
1,1,1-trichloroethane	3	1
Phenol, single compound	1	1
Naphthalene	10	4
Phenols	9	3

Table 5-4

EPA Permit Compliance System Violations (1992)

Parameter	Number of Violations	Number of Companies
Dissolved oxygen (DO)	14	6
BOD, 5-day (20 deg. C)	33	13
Chemical oxygen demand (COD)	3	3
pH	237	53
Total suspended solids	211	58
Oil and grease	174	46
Nitrogen, Ammonia Total (as N)	50	20
Total phosphorous (as P)	1	1
Total organic carbon	2	1
Total cyanide	36	10
Free cyanide (amen. to chlorination)	6	4
Total cadmium	1	1
Hexavalent chromium	23	6
Total chromium	14	9
Total copper	12	5
Total iron	29	8
Dissolved iron	1	1
Total lead	72	19
Total manganese	2	1
Total nickel	10	6
Total silver	1	1
Total zinc	113	26
Total antimony	2	1
Total aluminum	3	1

Table 5-4 (Continued)

EPA Permit Compliance System Violations (1992)

Parameter	Number of Violations	Number of Companies
Total recoverable phenolics	48	11
Benzene	1	1
Benzo(a)pyrene	1	1
1,1,1-trichloroethane	1	1
Naphthalene	13	3
Phenols	14	3

Table 5-5

EPA Permit Compliance System Violations (1993)

Parameter	Number of Violations	Number of Companies
Dissolved oxygen (DO)	5	3
BOD, 5-day (20 deg. C)	7	4
pH	232	59
Total suspended solids	150	54
Oil and grease	119	43
Nitrogen, Ammonia Total (as N)	33	15
Total organic carbon	1	1
Total cyanide	27	11
Free cyanide (amen. to chlorination)	1	1
Total cadmium	2	1
Hexavalent chromium	11	4
Total chromium	12	4
Total copper	10	3
Total iron	17	8
Total lead	53	13
Total nickel	16	9
Total silver	14	2
Total zinc	99	29
Total recoverable phenolics	29	11
Benzo(a)pyrene	1	1
1,1,1-trichloroethane	2	1
Naphthalene	4	2
Phenols	2	2

Table 5-6

EPA Permit Compliance System Violations (1994)

Parameter	Number of Violations	Number of Companies
Dissolved oxygen (DO)	6	4
BOD, 5-day (20 deg. C)	22	8
pH	133	47
Total suspended solids	100	44
Oil and grease	67	36
Nitrogen, Ammonia Total (as N)	32	14
Total organic carbon	1	1
Total cyanide	23	9
Free cyanide (amen. to chlorination)	10	3
Total cadmium	1	1
Hexavalent chromium	19	9
Total chromium	12	6
Total copper	9	5
Total iron	19	7
Dissolved iron	2	1
Total lead	26	9
Total manganese	1	1
Total nickel	5	5
Total silver	7	2
Total zinc	59	27
Total tin	1	1
Total aluminum	1	1
Total selenium	1	1
Total recoverable phenolics	28	9

Table 5-6 (Continued)

EPA Permit Compliance System Violations (1994)

Parameter	Number of Violations	Number of Companies
Benzo(a)pyrene	3	3
Naphthalene	2	2
Phenols	7	4

6.0 NEW AND INNOVATIVE APPROACHES

6.1 Production Technologies

(a) A considerable amount of research is currently underway into new iron and steelmaking processes that would eliminate or substantially minimize the need for coke. Among these is a $55 million Direct Steelmaking research project funded primarily by the Department of Energy.[27] The purpose of this project is to determine whether direct steelmaking without production of coke and molten iron in separate processes can be a commercially viable technology. Processes to produce molten iron directly from coal and iron-bearing materials are also being evaluated. Because these processes have not yet been demonstrated on a commercial scale at this time, they are judged not to be suitable to form the basis for revised BAT effluent limitations guidelines and NSPS. Furthermore, the capital investment required to implement such processes across the industry for existing mills within the compliance schedule required by the CWA would most likely be prohibitive. In the long term, these projects may provide substantial benefits for the integrated segment of the industry in the form of lower capital investments for upgrades and modernization; improved production scheduling and productivity through use of multiple parallel production units instead of a smaller number of large units that must be periodically taken out of service; and substantially lower air emissions and wastewater discharges than current operations.

(b) In the United States, nearly all of the blast furnace coke is produced in by-product coke plants with their costly and difficult air and water pollution control problems. There is one commercial-scale nonrecovery coke battery operated for production of blast furnace coke by Sun Coal Company in

Vansant, Virginia. The coke battery comprises adjacent horizontal, dome-shaped ovens constructed to allow combustion of the gasses evolved from the coal during coking, thus consuming the by-products that are recovered in by-product recovery coke plants. The process allows for energy recovery and results in substantially lower air emissions and virtually no cokemaking process wastewater discharges compared to by-product coke plants. Inland Steel announced plans to replace its coke plants with nonrecovery coke batteries but later abandoned those plans for financial reasons.[70]

(c) A patent application is pending for a continuous, closed process to pyrolize coal in circular tubes (ovens) which are indirectly heated with a portion of the gas produced. The process is being developed by Calderon Energy Company of Bowling Green, Ohio. Calderon reports the following major components of the process:

- Positive displacement of coal feed and coke discharge;
- Horizontal pyrolysis of coal for consolidation;
- Integrated dry steam quenching of coke;
- Hot cleanup of raw gas yielding cracked desulfurized gas;
- Regeneration of sorbent yielding elemental sulfur; and
- Provision of lockhoppers for charging coal, discharging coke, and sorbent handling.

Calderon reports that the process will generate no fugitive or process emissions and that wastewater treatment will not be required because the process cracks all coal distillation products (tars, ammonia, light oils). Calderon reports that the process will result in three products: coke of high

stability, desulfurized syngas rich in hydrogen, and elemental sulfur. The process has not been demonstrated on a commercial scale as of this writing.

(d) Pulverized coal injection for blast furnace operations is a technology that uses raw material substitution. In this process, pulverized coal is injected into the blast furnace through the tuyeres, thus supplying part of the carbon required to reduce the iron-bearing materials to molten iron. This reduces the coke demand for furnace operations and eliminates the air emissions and wastewater discharges that would have occurred from production of the displaced coke. The project team is not aware of any studies that fully characterize blast furnace recycle system discharges from furnaces operated with pulverized coal injection. Injection of oil and pulverized coal into blast furnaces is demonstrated in the U.S. iron and steel industry.

(e) Although continuous casting is not a new process, it has only been implemented on a large scale in the United States during the last fifteen years (see Figure 2-9). This process results in substantial productivity improvements, energy and manpower savings, and effluent reduction benefits. The effluent reduction benefits accrue because virtually all continuous casters are installed with high-rate recycle systems for cooling and process waters. These systems replace blooming and slab mills that typically have considerably higher water usage and effluent discharges.

Most continuous casters installed to produce flat rolled products are configured to produce slabs ranging from 8 to 10 inches in thickness. Breakdown of these slabs into strips requires a complete hot strip mill equipped with reheat furnaces, several roughing stands, and a set of finishing stands. There is one nonintegrated mill that is equipped with two, thin-slab

casters to produce two-inch thick slabs. These slabs are hot-charged into a normalizing furnace, processed in one descaling stand, and then processed in a set of finishing stands. Recently, Acme Metals, Inc., one of the smallest integrated steel makers, announced plans to install a thin slab caster to produce flat-rolled carbon steels for selected markets.[71] The use of thin slab casting allows for lower capital investment requirements for entry into some of the flat rolled steel markets, and results in effluent reduction benefits from reduced water usage and discharge from hot strip mills.

(f) A number of new continuous strip finishing mills have been constructed during the last five to seven years. As noted earlier, several steel finishing and metal finishing operations are often combined in one or two continuous production lines compared to many separate mills. These newer mills offer the potential for effluent reduction benefits over separate processes. The project team is not aware of any studies that fully characterize effluent discharges from these mills.

6.2 Wastewater Flow Minimization and Improved Wastewater Treatment

Aside from process modifications that would result in changes in the volume and character of process wastewaters, there are three principal methods to reduce mass discharges of pollutants to the environment from iron and steel manufacturing operations:

- Wastewater flow minimization through process water conservation, process water reuse, and process water recycle;
- Improved end-of-pipe wastewater treatment to lower concentrations of discharged pollutants; and,
- Effluent disposal by nondischarge methods including evaporation on slags, incineration in furnaces, and deep well disposal.

When considering the CWA goal of zero discharge of pollutants for iron and steel manufacturing operations, wastewater flow minimization must be a first priority. For many of the basic steelmaking operations, opportunities to minimize or eliminate the discharge of pollutants become feasible only if process wastewater flows are minimized through high-rate recycle.

6.2.1 Wastewater Flow Minimization

Since Part 420 was promulgated in 1982, better performing mills in the U.S. iron and steel industry have significantly improved wastewater flow minimization through increased high-rate recycle, cascading process water from one operation to another, and alternate effluent disposal methods. Process water discharge rates at many of the mills highlighted in Section 4.3 as better performing mills are substantially below those used by EPA as model process wastewater flows to establish the effluent limitations guidelines and standards. Except for cokemaking and steel finishing operations, performance better than the ELG LTAs shown on Figures 4-1 through 4-8 is principally attributable to reductions in process wastewater discharges.

6.2.2 Improved Treatment Methods and Treatment Operations

Also demonstrated by the better performing mills are improved wastewater treatment methods and enhanced treatment system operations. These include:

- Operation of coke plant wastewater treatment systems without ammonia stripping as a pretreatment;

- Improved operation of coke plant biological treatment systems by adding enhanced biocultures;

- Combined metals precipitation and alkaline chlorination treatment of pretreated coke plant wastewaters and blast furnace recycle system blowdown;

- Combined treatment of sinter plant and blast furnace blowdowns in an advanced metals precipitation system;

- Innovative treatment of wastewaters resulting from BOF suppressed combustion emission controls that permits operation with zero discharge for extended periods;

- Cascading of recycle system blowdowns from basic steelmaking operations (BOF, vacuum degassing, continuous casting) to minimize process wastewater discharges;

- Combined treatment of a blowdown from a hot strip mill high-rate recycle system with blowdowns from other high-rate recycle systems in a metals precipitation and filtration system; and

- Operation of a combination of pretreatment and end-of-pipe wastewater treatment systems to achieve minimal discharges from steel finishing operations.

6.3 Pollution Prevention

For purposes of this report, *"pollution prevention"* is used in the context of EPA's definition of the term: *"... the use of processes, practices or products that reduce or eliminate the generation of pollutants."* EPA advocates a hierarchial approach to pollution prevention which focuses first upon *"source reduction"* as a means to reduce or eliminate waste, and second upon *"recycling"* to reuse or reclaim used materials and waste. Historically, the iron and steel industry used pollution prevention as an integral part of its operations. However, most of the following pollution prevention techniques are examples of recycling, rather than examples of source reduction:

- Recovery of by-products from cokemaking operations (crude coal tars, crude light oils, anhydrous ammonia or ammonium sulfate, sodium phenolate) for use or processing into final products elsewhere;
- Reprocessing of coke plant tar decanter sludges and wastewater treatment sludges in coke ovens;
- Recovery of iron values from blast furnace flue dusts, blast furnace wastewater sludges and mill scale, and consumption of coke breeze in sinter plants;
- Processing and reuse of blast furnace and steelmaking slags for use in the road building, construction, and railroad industries;
- Remelting and processing of home scraps, prompt industrial steel scraps, and dormant steel scraps in BOFs and EAFs to make new steel;
- Collection and recovery of EAF flue dusts for recovery of lead and zinc values;
- Recovery and processing of recovered waste lubricating oils and rolling solutions for use as fuel supplements;
- Regeneration of spent acid pickling liquors for reuse and use of spent pickling liquors as treatment aids for POTWs; and
- Collection of dross from hot coating operations for recovery of metal values at off-site processors.

Examples of source reduction in the iron and steel industry include the alternative ironmaking and steelmaking processes briefly reviewed in Section 6.1: nonrecovery cokemaking instead of by-product cokemaking and continuous casting instead of the combination of ingot casting and primary rolling. Nonintegrated steelmaking with EAFs instead of integrated steelmaking with intermediate production of coke, sinter, and molten iron could also be considered source reduction. Because EAF steelmaking cannot currently be used to produce all grades of steel products, and cannot be used to produce all steel products at current demand rates, it would not be practical to base a revised single media or multimedia regulation on this technology.

A primary pollution prevention technique to eliminate wastewater discharges is use of dry air emission and gas cleaning controls instead of wet or semi-wet controls where possible (see Section 5.6). Other available pollution prevention techniques regarding wastewater treatment include high-rate process water and process wastewater recycle for sintering, ironmaking, steelmaking, vacuum degassing, continuous casting, and hot forming operations, flow reduction through other means for steel finishing operations (e.g., cascade rinsing and fume scrubber recycle for acid pickling lines), and cascading of recycle system blowdowns from one operation to another. These technologies are well demonstrated in the U.S. iron and steel industry, but not universally applied.

One example of an innovative process wastewater treatment and recycle system is that operated by LTV Steel for the suppressed combustion BOF shop at its Cleveland Works. The process water treatment system for the furnace air emission control wet scrubbers is operated in a water softening mode such that LTV Steel operates with no discharge for extended periods of time. Relatively low-volume, intermittent discharges are made to a nearby continuous caster recycle system. The total discharge of toxic metals from the BOF system is substantially lower than the effluent limitations derived from the applicable effluent limitations guidelines.[72]

A potential innovative approach for disposing of a blowdown from a combined blast furnace/sinter plant recycle system is being explored by U.S. Steel at its Gary Works.[67] U.S. Steel has applied for a permit from the Indiana Department of Environmental Management to pilot test incineration of the blast furnace/sinter plant blowdown in BOF steelmaking gas cleaning systems. This project is designed to eliminate a wastewater source by evaporating the blowdown and incinerating the nonmetal pollutants. The metals present would be transferred to the BOF gas cleaning water and treated with metals normally found in BOF wastewaters. It is expected that the pilot testing will occur during the next year.

6.4 Residuals Management

The iron and steel industry generates large quantities of residuals from the primary ironmaking and steelmaking processes and wastewater treatment sludges from all industry operations. Table 6-1 summarizes the more common practices for beneficially reusing or disposing of residuals.

Virtually all residuals from by-product cokemaking operations are either recovered as crude by-products (e.g., crude coal tar, crude light oil, ammonium sulfate), collected and reused or sold (e.g., coke breeze), or recycled to the coke ovens for recovery of carbon values (e.g., coal tar decanter sludge, coke plant wastewater treatment sludge). Ironmaking and steelmaking slags generated at most integrated steel mills are processed and beneficially reused in a variety of construction and road building uses. Blast furnace flue dusts and blast furnace gas wash water wastewater treatment sludges are recovered through sinter plants at less than half the blast furnace plants. These materials are recovered through cold briquetting at one known mill. Other wastewater treatment sludges are landfilled at nearly all mills.

Continuous caster and hot forming mill scales are recovered on site at mills with sinter plants, recovered off site in cement manufacturing, or are landfilled at a number of mills. Wastewater treatment sludges from hot forming operations are generally not recovered or recycled because of high oil content. Similarly, wastewater treatment sludges from finishing operations are generally not recovered because of high oil and metals content. Although these sludges are relatively high in iron content, it is not currently economical to process and recover the iron from the sludges.

6.5 Best Management Practices

Part 420 does not contain best management practices (BMPs). Because of the extensive raw material handling and the nature of cokemaking, sintering, ironmaking, and steelmaking operations, a considerable number of discharges are not currently regulated by Part 420 or by most NPDES permits. These unregulated discharges have been the subject of remediation actions sought

by EPA in steel industry enforcement actions.[66,68,73] A more effective and uniform means to control such discharges would be to require BMPs as part of 40 CFR Part 420. Following is a partial list of potential BMPs:

- Control of spillage and losses from raw material unloading operations (ore docks);
- Control of runoff from raw material storage piles: coal, coke, iron ore, limestone, scrap steel;
- Control of fugitive discharges of process waters, process wastewaters, and process materials to coke plant, blast furnace, and sinter plant noncontact cooling water (NCCW);
- Control of coke oven and blast furnace gas condensates;
- Control of runoff/leachate and groundwater contamination from coke batteries, coke quench tower sumps, and by-product recovery areas;
- Control of runoff/leachate and groundwater contamination from blast furnace slag pits located at the furnaces;
- Control of runoff from blast furnace and steelmaking slag processing located at the furnaces and in remote areas (almost always operated by contractors);
- Control of runoff from EAF dust collection areas;
- Control of spillage and runoff from loading stations for rolling solutions and pickling acids; and
- Surveillance and corrective action programs for oil discharges from large NCCW flows.

Table 6-1

Common Practices for Residuals Management

Process Operation	Residual	Reuse/Disposal Practices
Cokemaking	Crude coal tar	Recovered and sold as by-product
	Crude light oil	
	Ammonium sulfate	
	Ammonia	
	Coke breeze	
	Tar decanter sludge	Returned to coke ovens
	Wastewater treatment sludge	
Ironmaking	Blast furnace slag	Processed and sold as by-product
	Flue dust	Recovered in sinter plants; cold briquetted; landfilled
	Wastewater sludge	
Steelmaking	BOF slag	Processed and sold as by-product
	EAF slag	Processed for recovery of metals
	Wastewater sludge	Landfilled; cold briquetted and reused
Continuous Casting	Mill scale	Landfilled; recovered in sinter plants
Hot Forming	Mill scale	Recovered in sinter plants; recovered in cement manufacturing; landfilled
	Waste oils	Recovered and used as fuel supplement
	Wastewater sludge	Landfilled
Finishing operations	Waste pickling acids	Regenerated and reused; reused as municipal wastewater treatment aide; neutralized and discharged
	Waste oils	Recovered and used as fuel supplement
	Wastewater sludges	Landfilled

7.0 REFERENCES

1. 47 FR 23258. Part II; Environmental Protection Agency; Iron and Steel Manufacturing Point Source Category Effluent Limitations Guidelines and Standards; May 27, 1982.

2. Settlement Agreement for Case No. 82-3225 and Consolidated Cases; National Steel Corporation, et.al., Petitioners v. U.S. Environmental Protection Agency, Respondent and Natural Resources Defense Council, Inc., Intervenor-Respondent; U.S. Court of Appeals for the Third Circuit; February 24, 1993.

3. 49 FR 21036. Part II; Environmental Protection Agency; Iron and Steel Manufacturing Point Source Category Effluent Limitations Guidelines and Standards; May 17, 1984.

4. Consent Decree for Civil No. 89-2980; Natural Resources Defense Council, Inc.; Public Citizen, Inc., Plaintiffs v. William K. Reilly, Administrator, U.S. Environmental Protection Agency, Defendant, and American Paper Institute; National Forest Products Association; et al., Intervenor-Defendants; United States District Court for the District of Columbia; January 31, 1992.

5. 47 FR 23266. May 27, 1982.

6. American Iron and Steel Institute; Steel Works, U.S. Steel Industry at a Glance; Washington, D.C., 1992.

7. Association of Iron and Steel Engineers; ***The Making, Shaping and Treating of Steel***; ISBN 0-930767-00-4; Pittsburgh, PA; 1985.

8. U.S. EPA; ***Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category***, Vol. I; EPA 440/1-82/024; Washington, D.C.; May 1982.

9. U.S. EPA; ***Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category***, Vol. II (Cokemaking); EPA 440/1-82/024; Washington, D.C.; May 1982.

10. Personal communication between Gary A. Amendola, P.E., Amendola Engineering, Inc., Lakewood, OH and K.C. Shaw, P.E., Chief Engineer - Environment, Geneva Steel, Provo, UT; June 16, 1994.

11. U.S. International Trade Commission; ***Metallurgical Coke: Baseline Analysis of the U.S. Industry and Imports***; Publication 2745; Washington, D.C.; March 1994.

12. U.S. EPA; ***Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category***, Vol. II (Sintering); EPA 440/1-82/024; Washington, D.C.; May 1982.

13. U.S. EPA; ***Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category***, Vol. II (Ironmaking); EPA 440/1-82/024; Washington, D.C.; May 1982.

14. BOF Roundup; **33 Metal Products**; May 1991; p.35.

15. U.S. EPA; ***Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category***, Vol. III (Steelmaking); EPA 440/1-82/024; Washington, D.C.; May 1982.

16. U.S. EPA; ***Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category***, Vol. III (Vacuum Degassing); EPA 440/1-82/024; Washington, D.C.; May 1982.

17. U.S. EPA; ***Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category***, Vol. III (Continuous Casting); EPA 440/1-82/024; Washington, D.C.; May 1982.

18. U.S. EPA; ***Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category***, Vol. IV (Hot Forming); EPA 440/1-82/024; Washington, D.C.; May 1982.

19. U.S. EPA; ***Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category***, Vol. V (Salt Bath Descaling); EPA 440/1-82/024; Washington, D.C.; May 1982.

20. U.S. EPA; ***Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category***, Vol. V (Acid Pickling); EPA 440/1-82/024; Washington, D.C.; May 1982.

21. U.S. EPA; ***Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category***, Vol. VI (Cold Forming); EPA 440/1-82/024; Washington, D.C.; May 1982.

22. American Iron and Steel Institute; ***Directory of Iron and Steel Works of the United States and Canada***; Washington, D.C.; 1977.

23. Association of Iron and Steel Engineers; ***Directory of Iron and Steel Plants***; Pittsburgh, PA; 1994.

24. American Iron and Steel Institute; ***Statistical Highlights, U.S. Iron and Steel Industry***; Washington, D.C.; 1983.

25. American Iron and Steel Institute; ***Annual Statistical Report, 1988***; Washington, D.C.; 1989.

26. American Iron and Steel Institute; ***Annual Statistical Report, 1992***; Washington, D.C.; 1993.

27. American Iron and Steel Institute; ***Statistical Highlights, U.S. Iron and Steel Industry***; Washington, D.C.; 1993.

28. Personal communication between Gary A. Amendola, P.E., Amendola Engineering, Inc., Lakewood, OH and Mary Johnson, Statistics Department, American Iron and Steel Institute, Washington, D.C., August 9, 1994.

29. American Iron and Steel Institute; ***Capital Expenditures by Reporting Companies for Domestic Environmental Control and Solid Waste Disposal Facilities***; AIS 17EC; Washington, D.C., 1993.

30. American Iron and Steel Institute; ***AISI News***; Washington, D.C.; June 1994.

31. 39 FR 24114-24133. 40 CFR Part 420, Subparts A - L.

32. *American Iron and Steel Institute, et. al., v EPA,* 526 F.2d 1027 (3rd Circuit, 1975)

33. 39 FR 12990-13030. 40 CFR Part 420, Subparts M - Z.

34. *American Iron and Steel Institute, et. al., v EPA,* 568 F.2d 284 (3rd Circuit, 1977)

35. 40 FR 1858 - 1907. Part II; Environmental Protection Agency; Iron and Steel Manufacturing Point Source Category Effluent Limitations Guidelines and Standards; January 7, 1981.

36. 47 FR 23266. May 27, 1982.

37. 47 FR 23265. May 27, 1982.

38. Industrial Economics, Incorporated; ***The Use and Impact of Iron and Steel Industry Intra-Plant Trades***; Cambridge, MA; March 1994.

39. Ontario Ministry of the Environment. ***Status Report on the Effluent Monitoring Data for the Iron and Steel Sector for the Period from November 1, 1989 to October 31, 1990***; Water Resources Branch; Toronto, Ontario; September 1991.

40. Hatch Associates Ltd. ***Inventory and Costing of Best Available Pollution Control Technologies for the Iron and Steel Sector in Ontario***; (Final Draft Report); Mississauga, Ontario; September 1991.

41. U.S. EPA File Information. Central Treatment Rulemaking Record. September 27, 1984. Washington, D.C. (Draft Proposed Modification to 40 CFR Part 420).

42. Mr. Joseph S. Kocot (Director - Plant Maintenance and Engineering, National Steel Corporation, Granite City Division, Granite City, Illinois) to Mr. Timothy R. Kluge P.E. (Manager, Industrial Unit, Permit Section, Illinois Environmental Protection Agency, Springfield, Illinois); June 25, 1992; 3 pp w/attachments.

43. Mr. James H. Scarbrough (Chief, Water Permits and Enforcement Branch, Water Management Division) to Mr. John Poole (Chief, Industrial Branch, Water Division, Alabama Department of Environmental Management, Montgomery, Alabama); June 29, 1993; 3 pp w/attachments.

44. Personal communication between Gary A. Amendola, P.E., Amendola Engineering, Inc., Lakewood, OH and Irvin Dzikowski, Chief, Permits Section, Water Management Division, U.S. EPA Region V, Chicago, IL; August 2, 1994.

45. Personal communication between Gary A. Amendola, P.E., Amendola Engineering, Inc., Lakewood, OH and Karen Buerki, Enforcement Section, Water Management Division, U.S. EPA Region 4, Atlanta, GA; June 1993.

46. 47 FR 23273. May 27, 1982.

47. 49 FR 21025. May 24, 1984.

48. Esposito, M.P., Tiernan, T.O. and Dryden, F.E., ***Dioxins***, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, EPA-600/2-80-197, November 1980.

49. U.S. Environmental Protection Agency, ***National Dioxin Study Report to Congress***, Office of Solid Waste and Emergency Response, Washington, D.C., August 1987, EPA/530-SW-87-025.

50. U.S. Environmental Protection Agency, ***The National Dioxin Study - Tiers 3,5,6, and 7***, Office of Water Regulations and Standards, Washington, D.C., February 1987, EPA-440/4-87-003.

51. Amendola, G.A., Barna, D., Blosser, R., LaFleur, L., McBride, A., Thomas, F., Tiernan, T., and Whittemore, R., ***The Occurrence and Fate of PCDDs and PCDFs in Bleached Kraft Pulp and Paper Mills***, *Chemosphere*, Volume 18, Nos. 1 - 6, 1989.

52. U.S. Environmental Protection Agency, ***U.S. EPA/Paper Industry Cooperative Dioxin Screening Study***, Office of Water Regulations and Standards, Washington, D.C., March 1988, EPA 440/1-88-025.

53. Oberg, T. and Allhammar, G. ***Chlorinated Aromatics from Metallurgical Industries - Process Factors Influencing Production and Emissions***, *Chemosphere*, Volume 19, Nos. 1 - 6, pp 711 - 716, 1989.

54. Tysklind, M., Soderstrom, G., Rappe, C., Hagerstdet, L.E., and Burstrom, E. ***PCDD and PCDF Emissions from Scrap Metal Melting Processes at a Steel Mill***, *Chemosphere*, Volume 19, Nos. 1 - 6, pp 705 - 710, 1989.

55. Antonsson, A.B., Rumark, S., and Mowrer, J. ***Dioxins in the Work Environment in Steel Mills***, *Chemosphere*, Volume 19, Nos. 1 - 6, pp 699 - 704, 1989.

56. Colburn, C. and Clement, C., ***Chemically-Induced Alterations in Sexual and Functional Development: the Wildlife/Human Connection***. In: (ed) Princeton Scientific, Princeton, pp 1-403, 1992.

57. White, R., Jobling, S., Hoare, S.A., Sumpter, J.P., and Parker, M.G., ***Environmentally Persistent Alkylphenolic Compounds are Estrogenic,*** *Endoctrinology*: 135:175-182, 1994.

58. Naylor, G.C., Mierure, J.P., Weeks, J.A., Castaldi, F.J., and Romano, R.R., ***Alkylphenol Ethoxylates in the Environment.*** *Journal of the Society of American Oil Chemists*: 69:695-703, 1992.

59. Ahel, M., Conrad, J. and Giger, W., ***Persistent Organic Chemicals in Sewage Effluents. III. Determination of nonylphenoxy carboxylic acids by high resolution gas chromatography/mass spectroscopy and high performance liquid chromatography.*** *Environmental Science and Technology*: 21:697-703, 1987.

60. Giger, W., Ahel, M., Koch, M., Laubscher, H.U., Schaffner, J. and Schneider, J., ***Behavior of Alkylphenol-polyethoxylate Surfactants and of Nitriloacetate in Sewage Treatment.*** *Water Science and Technology*: 19:449-460, 1987.

61. Zoller, U., ***Groundwater Contamination by Detergents and Polycyclic Aromatic Hydrocarbons - A Global Problem of Organic Contaminants: Is the Solution Locally Specific?*** *Water Science and Technology*: 27:187-194, 1993.

62. Clark, L.B., Rosen, R.T., Hartman, T.G., Louis, J.B., Stuffet, I.H., Lippincott, R.L., and Rosen, J.D., ***Determination of Alkylphenol Ethoxylates and their Acetic Acid Derivatives in Drinking Water by Particle Beam Liquid Chromatography/Mass Spectroscopy.*** *International Journal of Environmental Analytical Chemistry*: 47:167-180, 1992.

63. Personal communications between Gary A. Amendola, P.E., Amendola Engineering, Inc., Lakewood, OH, and Peter Howe, Permits Section, Water Management Division, U.S. EPA Region 5, Chicago, IL; September 1, 9, and 26, 1994.

64. 304(l) lists.

65. USX/Kobe Dredging Consent Decree.

66. Consent Decree for Civil Action No. 88-558; United States of America, Plaintiff v. USX Corporation, Defendant; United States District Court for the Northern District of Indiana; 1990.

67. Personal communication between Gary A. Amendola, P.E., Amendola Engineering, Inc., Lakewood, OH and J. David Moniot, General Manager - Environmental Affairs and Water Manager, U.S. Steel, Pittsburgh, PA; September 1, 1994.

68. Consent Decree for Civil Action No. H88-0328; United States of America, Plaintiff v. Inland Steel Company, Defendant; United States district Court for the Northern District of Indiana, Hammond Division; March 8, 1993.

69. Personal communication between Gary A. Amendola, P.E., Amendola Engineering, Inc., Lakewood, OH and Mark O. Moloney, Environmental Engineer, U.S. Environmental Protection Agency, Region 5, Environmental Sciences Division, Eastern District Office, Westlake, OH; May 27, 1994.

70. Personal communication between Gary A. Amendola, P.E., Amendola Engineering, Inc., Lakewood, OH and Robert D. Johnston, Staff Engineer, Environmental, Health and Safety, Inland Steel Company, East Chicago, IN, September 7, 1994.

71. Newspaper Article: ***Steel Producer Plans 'Hybrid' Mill***; Chicago Tribune; Thursday, August 16, 1994.

72. Amendola, G.A. and Safavi, B.; LTV Steel Company - Cleveland Works Pollution Prevention Case Study; 1992 (Draft Report).

73. Consent Decree for Case No. C2 88-216; United States of America, Plaintiff v. Wheeling-Pittsburgh Steel Corporation, Defendant; United States District Court for the Southern District of Ohio Eastern Division; 1991.

8.0 GLOSSARY

Acid Furnace A furnace lined with acid brick as contrasted to one lined with basic brick. In this instance the terms acid and basic are in the same relationship as the acid anhydride and basic anhydride that are found in aqueous chemistry. The most common acid brick is silica brick or chrome brick.

Acid Steel Steel made in a furnace or converter lined with siliceous (acid) refractory material. In the open hearth and electric furnaces employing the acid process, the hearth or bottom consists of fritted ("burned in") silica sand. The acid bessemer converter usually was lined with a kind of sandstone called "firestone". Raw materials for acid steel must be low in phosphorus and sulfur.

Additions Materials which are added to the molten bath of steel or to the molten steel in the ladle to produce the chemical composition required for the specific steel order.

Air Cooled Slag Slag which is cooled slowly in large pits in the ground. Light water sprays are generally used to accelerate the cooling over that which would occur in air alone. The finished slag is generally gray in color and looks like a sponge.

Alloy A substance that has metallic properties and is composed of two or more chemical elements of which at least one is a metal.

Alloying Materials Additives to steelmaking processes for improving the properties of the finished products. Chief alloying elements in medium alloy steels are: nickel, chromium, manganese, molybdenum, vanadium, silicon, and copper.

Alloy Scrap Scrap steel which contains one or more alloying metals such as nickel, chromium, manganese, molybdenum, tungsten, vanadium, silicon, or copper. Such scrap must be very carefully classified according to composition and kept separate from other kinds of scrap.

Alloy Steel Steel is classified as alloy when the maximum of the range given for the content of alloying elements exceeds one or more of the following: manganese, 1.65%; silicon, 0.60%; copper, 0.60%; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, boron, chromium up to 3.99%, cobalt, niobium (columbium), molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying element added to obtain a desired alloying effect.

Aluminum A metallic chemical element. (1) In either the bessemer, open hearth or electric furnace processes, it is (or was) used as a deoxidizer, by adding it to the molten steel either in the ladle or in the mold to remove oxygen and thereby control, or entirely eliminate, the escape of gas (called "killing"). Aluminum may also be added for the control of grain size, and occasionally as an alloying element. (2) A light weight metal. It weighs 28% as much as carbon steel.

Ammonia Liquor Primarily water condensed from the coke oven gas, an aqueous solution of ammonium salts of which there are two kinds; free and fixed. The free salts are those which are decomposed on boiling to liberate ammonia. The fixed salts are those which require boiling with an alkali such as lime or sodium hydroxide to liberate the ammonia.

Ammonia Still The free ammonia still is simply a steam stripping column where ammonia gas is removed from ammonia liquor. The fixed still is similar except lime or, more commonly, sodium hydroxide, is added to the liquor to liberate ammonia from its compounds so it can be steam stripped.

Ammonia Still Bottoms Treated effluent from an ammonia still.

Angle A very common structural or bar shape with two legs of equal or unequal length intersecting at 90°.

Annealing Either batch or continuous heat treatment applied to cold rolled or cold formed steel to soften the steel and modify other mechanical and physical properties, or to produce a definite microstructure.

Apron Rolls Rolls used in the casting strand for keeping cast products aligned.

Bar, Hot Rolled Produced from ingots, blooms, or billets covering the following range: Rounds, 3/8 to 8-1/4 in. incl.; Squares, 3/8 to 5-1/2 in.; Round cornered squares, 3/8 to 8 in. incl.; Hexagons, 1/4 to 4-1/16 in. incl.; Flats, 13/64 (0.2031) in. and over in specified thicknesses and not over 6 in. specified width.

Standard and special shapes: Angles, channels, tees, and zees, when their greatest cross-sectional dimension is under 3 in. Ovals, half ovals, and half rounds. Special shapes.

Base Box A unit of measure peculiar to the tin plate industry. It corresponds to an area equivalent to 112 sheets of tin plate, 14 x 20 in. each; or, 31,360 sq. in.; or, 217.78 sq. ft.

Basic Bottom and Lining In a melting furnace, the inner lining and bottom are composed of either crushed burned dolomite, magnesite, magnesite bricks, or basic slag. These materials have a basic reaction in the melting process.

Basic Brick A brick made of a material which is a basic anhydride such as MgO or mixed MgO plus CaO. See acid furnace.

Basic Furnace A furnace in which the refractory material is composed of dolomite or magnesite.

Basic Material A chemical expression meaning the opposite of acid. Basic and acid materials, when brought together so that they can react, neutralize each other, forming salts or slags. In such reactions, the base becomes the positive part of the salt and the acid the negative. Examples of basic materials; limestone (or lime, CaO), magnesite (MgO), dolomite (containing both CaO and MgO). Examples of acid materials; quartzite or silica (SiO_2) and the various clays, oxides of sulfur, etc. In metallurgy, the terms, "bases" and "acids," are applied to refractories, fluxes, and slags. Slags are said to be basic when the bases in them are greater than the acids; or to be acid when the acids in them are greater than the bases.

Basic Steel Steel melted in a furnace that has a basic bottom and lining, and under a slag that is dominantly basic.

Basic Oxygen Steelmaking The basic oxygen process is carried out in a basic lined furnace which is shaped like a pear. High pressure oxygen is blown vertically downward on the surface of the molten iron through a water cooled lance.

Battery	A group of coke ovens arranged side by side.
Beam	An important member of the structural steel family. There are three varieties; the standard H, I, and the side flange used for weight supporting purposes.
Billet	A semi-finished piece of steel which has resulted from rolling an ingot or a bloom. It may be square, but is never more than twice as wide as thick. Its cross-sectional area is usually not more than 36 sq. in.
Blackplate	Cold reduced sheet over 12 in. wide to less than 32 in., in cut length or coils, and within the uniform classification of Flat Rolled Carbon Steel Products.
Blast Furnace	A large, tall conical-shaped furnace used to reduce iron ore to molten iron or "hot metal".
Bloom	A semi-finished piece of steel, resulting from the rolling or forging of an ingot. A bloom is square or not more than twice as wide as thick, and usually not less than 36 sq. in. in cross-sectional area.
Blowdown	Volume of water discharged from process water or noncontact cooling water recycle system. For high-rate recycle systems, the blowdown may be less than 2% of recirculating water flow.
Box Annealing	A process of annealing a ferrous alloy in a suitable closed metal container with or without packing material in order to minimize oxidation. The charge is usually heated slowly to a temperature below the transformation range, but sometimes above or within it, and is then cooled slowly. This process is also called "close annealing" or "pot annealing."
Bosh	The bottom section of a blast furnace. The section between the hearth and the stack, where melting of iron starts.
Briquette	An agglomeration of steel plant waste material of sufficient strength to be charged to a blast furnace.
By-product Coke Processes	Process in which coal is carbonized in the absence of air to permit recovery of the volatile compounds and produce coke.
Burden	Solid feed to a blast furnace.

Bustle Pipe Large-diameter, refractory-lined pipe surrounding the bottom of a blast furnace near the bosh (inverted conical section of blast furnace where melting of iron starts). The bustle pipe is used to distribute the hot blast from the blast furnace stoves to the furnace through tuyeres located below the bosh.

Carbon Steel Steel which owes its properties chiefly to various percentages of carbon without substantial amounts of other alloying elements. Steel is classified as carbon steel when no minimum content of elements other than carbon is specified or required to obtain a desired alloying effect; when the specified minimum for copper does not exceed 0.40%; or the maximum content for the following does not exceed the percentage noted: manganese, 1.65; silicon, 0.60; copper, 0.60.

Cast Iron The metallic product obtained by reducing iron ore with carbon at a temperature sufficiently high to render the metal fluid and casting it in a mold.

Casting (1) A term applied to the act of pouring molten metal into a mold. (2) The metal object produced by such pouring.

Caustic Dip Immersion of a metal in a solution of sodium hydroxide to clean the surface, or, when working with aluminum alloys, to reveal the macrostructure.

Channels A common steel shape consisting of two parallel flanges at right angles to the web. It is produced both in bar sizes (less than 3 in.) and in structural sizes (3 in. and over).

Charge The minimum combination of skip or bucket loads of material which together provide the balanced complement necessary to produce hot metal in the blast furnace of the desired specification.

Chromium An alloying element added to alloy steel (in amounts up to about 1.50%) to increase hardenability. Chromium content of 4% or more confers special ability to resist corrosion, so that steel containing more than 4% chromium is called "stainless steel."

Clarification The process of removing undissolved materials from a liquid, specifically either by settling or filtration.

Clinkers Another name for sinter, the product of burning a fuel (coke fines, coke breeze) with limestone fines and a variety of fine iron-bearing materials including iron ore screenings, blast furnace gas cleaning wastewater sludges, and mill scale to form an agglomerated product suitable for charging to a blast furnace.

Closed Hood A system in which the hot gases from the BOF are not allowed to burn in the hood with outside air infiltration. These hoods cap the furnace mouth. Suppressed combustion.

Coating The process of covering steel with another material, primarily for corrosion resistance.

Cobble (1) A jamming of the line of steel sheet while being rolled in a hot strip mill. (2) A piece of steel which for any reason has become so bent or twisted that it must be withdrawn from the rolling operation and scrapped. Some reasons for cobbling are: Steel too cold, a bad end which cannot enter a pass, sticking to the roll and wrapping around it, etc.

Coke The carbon residue left when the volatile matter is driven off of coal by high temperature distillation.

Coke Battery A coke producing unit comprising numerous, adjoining, refractory-lined, slot-type top coke ovens; coal charging and coke pushing facilities; coke quench stations; coke oven gas collecting mains; and other appurtenant equipment.

Coke Breeze Undersize coke particles recovered from coke screening operations and coke quenching stations. Coke breeze is used as fuel in sintering operations or sold as a by-product.

Coke Wharf The place where coke is discharged from quench cars prior to screening.

Cold Pig Blast furnace metal which has been cast into solid pieces, usually weighing from 60 to 80 lbs.

Cold Rolled Products Flat-rolled products which have been finished by rolling the piece without heating (at approximately ambient temperature).

Conditioning The removal of surface defects (seams, laps, pits, etc.) from semi-finished steel in the form of blooms, billets, slabs. It may be accomplished by chipping, scarfing, grinding, or machining. In special cases, the steel may be pickled first so as to reveal more of the defects.

Continuous Casting A process for solidifying liquid steel in place of pouring it into ingot molds. In this process, the solidified steel is in the form of cast blooms, billets, or slabs. This eliminates the need for soaking pits and primary rolling.

Continuous Mill A mill composed of several stands of rolls arranged "in tandem", usually so close together that the steel being rolled is passing through several stands simultaneously. Examples: bar mills, hot strip mills, and some recently constructed plate mills.

Creosote Distillate from tar.

Crop End The end or ends of an ingot or rolled product that contain the pipe or other defects to be cut off and discarded; also termed "discard."

Dephenolizer A facility in which phenol is removed from ammonia liquor and is recovered as sodium phenolate by liquid extraction and vapor recirculation.

Deoxidize In the limited sense used in metallurgy, the removing of oxygen from a heat of molten steel. Oxygen is present as iron oxide (FeO), which is dissolved in the steel, and is removed by adding a deoxidizing agent such as manganese, silicon, or aluminum.

Descaling The process of removing scale from the surface of steel. Scale forms most readily when the steel is hot by union of oxygen with iron. The most common method of descaling is to crack the scale by use of roughened rolls and a forceful water spray.

Double Slagging Process in which the first oxidizing slag is removed and replaced with a white, lime finishing slag.

Duplexing An operation in which a lower grade of steel is produced in a basic oxygen furnace and then an alloyed in the electric arc furnace.

Dustcatcher A part of the blast furnace through which the major portion of the dust is removed by mechanical separation.

Electric Arc Furnace	A furnace in which scrap iron, scrap steel, and other solid ferrous materials are melted and converted to finished steel. Liquid iron is rarely used in an EAF.
Electrostatic Precipitator	A gas cleaning device using the principle of placing an electrical charge on a solid particle which is then attracted to an oppositely charged collector plate. The collector plates are intermittently rapped to discharge the collected dust to a hopper below.
Evaporation Chamber	A method used for cooling gases to the precipitators in which an exact heat balance is maintained between water required and gas cooling; the design is to discharge no effluent as all of the water is supposed to be evaporated.
Extrusion	Shaping metal into a continuous form by forcing it through a die of appropriate shape.
Ferroalloy	An iron-bearing product, not within the range of those called steels, which contains a considerable amount of one or more alloying elements, such as manganese, silicon, phosphorus, vanadium, and chromium. Some of the more common ones are ferrochromium, ferromanganese, ferrophosphorus, ferrosilicon, and ferrovanadium. The chief use of these alloys is for making additions of their respective alloying elements to molten steel.
Ferrochrome	A finishing material which contains about 70% chromium. It is used as a chromium alloying material.
Ferromanganese	A product of the blast furnace, containing, besides iron, 78% to 82% manganese and some silicon, phosphorus, sulphur, and carbon. It is used as a deoxidizer and for alloying manganese.
Ferrophosphorus	A finishing material (see "finishing") which contains about 18% phosphorus. It is used as a phosphorus alloying material.
Ferrosilicon	A product of the blast furnace which contains 8 to 15% silicon. it is used as a deoxidizer and for alloying silicon.
Ferrous Metallurgy	That section of general metallurgy which embraces the science and knowledge applied to iron and steel products, their preparation, and adaptation to their uses.

Ferrovanadium A product which contains iron and about 38% vanadium. Used for alloying vanadium.

Fettling The period of time between tap and start.

Final Cooler An open packed tower for cooling coke oven gas by direct contact. The gas must be cooled to 30°C (86°F) for recovery of light oil. Open final coolers have been replaced with closed final coolers to control benzene emissions.

Finish In the steel industry, refers to the type of surface condition desired or existing in the finished product.

Finishing Materials Any material which may be added to purified molten steel in the latter stages of producing a heat of steel (i.e., for modifying its chemical composition).

Flat Sheet Sheet rolled as pieces of convenient size and then flattened or leveled, usually by stretching. This operation may produce properties slightly different from those of coiled sheet.

Flats Flat bars. They include all rectangular bars, except squares 13/64 in. and over in specified thickness, not over 6 in. in specified width.

Flattening Standard commercial flatness is obtained by roller leveling. This consists in passing sheets individually or in packs through a machine having a series of small diameter rolls.

Flume Flushing Process by which mill scale collected under hot forming mills and runout tables of continuous casters is transported with water to scale pits for recovery.

Flying Shear A shear which severs steel as the piece continues to move. In continuous mills, the piece being rolled cannot be stopped for the shearing operation, so the shear knives must move with it until it is severed.

Flushing Liquor Water recycled in the coke battery gas collecting main for the purpose of cooling the gas as it leaves the coke ovens.

Flux Material added to a fusion process for the purpose of removing impurities from the hot metal.

Forging (1) As a noun; a metal product which has been formed by hammering or pressing, (2) As a verb; forming hot metal into the desired shape by means of hammering or pressing.

Forming To shape or fashion with the hand, tools, mechanical equipment, or by a shape or mold.

Forming Properties Those physical and mechanical properties that allow a steel to be formed without injury to the steel in the finished product.

Four-High Mill A stand which has four rolls, one above the other. This kind of mill has two working rolls, each of which is stiffened by a larger back-roll. Four high rolls are used only on mills which roll flat products: slabs, plates, sheets, and strips.

Fourth Hole A fourth recovery lined hole in the roof of the electric arc furnace which serves as an exhaust port for furnace gases.

Free Leg A portion of old-design free and fixed ammonia stills from which ammonia, hydrogen sulfide, carbon dioxide, and hydrogen cyanide are steam distilled and returned to the gas stream.

Fugitive Emissions Emissions that are expelled to the atmosphere in an uncontrolled manner.

Furnace Burden The solid materials charged to a blast furnace comprising coke, iron ore and pellets, sinter, and limestone.

Gages Measurements of thickness. Examples of various standard gages are United States Standard Gage (USS), Galvanized Sheet Gage (GSG), Birmingham Wire Gage (BWG).

Galvanizing The process of applying a coating of zinc to the finished cold-reduced sheet or to fabricated parts made from strip products. The coating is applied by hot dipping or electrolytic deposition.

Galvannealed An extra tight coat of galvanizing metal (zinc) applied to a soft steel sheet, after which the sheet is passed through an annealing oven at about 1,200°F. The resulting coat is dull gray, without spangle, and especially suited for subsequent painting.

Grade The term grade designates divisions within different types based upon carbon content or mechanical properties.

Granulated Slag A product made by dumping liquid blast furnace slag past a high pressure water jet and allowing it to fall into a pit of water. The material has the appearance of light tan sand.

H-Steel Alloy steels that can be used in applications requiring different degrees of hardenability.

Hammer Forging A forging process in which the work is deformed by repeated blows. Compare with press forging.

Hammer Lap A defect on the surface of steel, being a folded over portion produced by bad practice in forging.

Hammer Welding Welding effected by heating close to their melting point the two surfaces to be joined, and hammering them until a firm union is made.

Hammering Beating metal sheet into a desired shape either over a form or on a high-speed mechanical hammer, in which the sheet is moved between a small curved hammer and a similar anvil to produce the required dishing or thinning.

Hard Drawn A temper produced in wire, rod, or tube by cold drawing.

Hardness Defined in terms of the method of measurement. (1) Usually, the resistance to dentation. (2) Stiffness or temper of wrought products. (3) Machinability characteristics.

Hearth In a reverberatory furnace, the portion that holds the molten metal or bath.

Heat Quantity of steel manufactured in a BOF or an EAF on a batch basis; the capacity of the furnace.

Hexagons A product of hot rolled carbon steel bars hexagonal in cross section. Commercial size range of hexagons, 1/4 to 5-1/2 in. inclusive.

High Strength Steel Low alloy steels forming a specific class in which enhanced mechanical properties and, in most cases, resistance to atmospheric corrosion are obtained by the incorporation of moderate proportions of one or more alloying elements other than carbon. The preferred terminology is "high-strength, low-alloy steels."

Holding Furnace A small furnace for maintaining molten metal from a larger melting furnace at the right casting temperature.

Hoop Special quality flat rolled steel product developed to meet the requirements of the cooperage industry in the manufacture of barrels, pails, and kegs. It is furnished in black or galvanized, and in cut lengths or coils, as specified.

Hot Bed A large area containing closely spaced rolls or rails for holding hot, partially rolled metal.

Hot Blast Preheated air blown into the blast furnace through a bustle pipe and numerous tuyeres located around the circumference of the furnace. Temperatures are in the range of 550°C to 1,000°C, and pressures are in the range of 2 to 45 atmospheres.

Hot Metal The molten iron product of a blast furnace; pig iron.

Hot Metal Furnace A furnace that is initially charged with solid materials followed by a second charge of melted liquid.

Hot Quenching A process of quenching in a medium at a temperature substantially higher than ambient temperature.

Hot Rolled Hot rolled products are those products that are rolled to finish at temperatures above the recrystallization temperature.

Hot Top A reservoir insulated to retain heat and to hold excess molten metal on top of an ingot mold in order to feed the shrinkage of the ingot. Also called "shrink head," or "feeder head".

Hot Working Plastic deformation of metal at such a temperature and rate that strain hardening does not occur. The lower limit of temperature for this process is the recrystallization temperature.

Hydraulic Shear A shear driven by water or oil pressure.

Immersion Coating Coating a metal with a second metal by immersing the first in a solution containing ions of the second.

Impact Extrusion A cold forming process in which the metal is forced by impact to flow around the punch, forming a tube with a solid bottom.

In Tandem	An arrangement of stands in a rolling mill, one after another, so that the piece being rolled can travel in one direction through a number of stands.
Indirect Extruction (Inverted)	An extrusion process in which the metal is forced back inside a hollow ram that pushes the die.
Induction Hardening	A process of hardening a ferrous alloy by heating it above the transformation range by means of electrical induction, and then cooling as required.
Induction Heating	A process of heating by electrical induction.
Ingot	A large block-shaped steel casting. Ingots are intermediates from which other steel products are made. When continuous casters are not used, an ingot is usually the first solid form the steel takes after it is made in a furnace.
Ingot Iron	Steel so low in carbon, silicon, manganese, phosphorus, sulphur and other metalloid content that it is commonly called "pure iron". Ingot iron is sometimes used for making enameling sheets. Also, silicon is sometimes added to "pure iron" to make high grade electrical sheets.
Ingot Mold	Cast iron molds into which molten steel is teemed. After cooling, the mold is stripped from the solidified steel which is then re-heated in soaking pits (gas or oil-fired furnaces) prior to primary rolling into slabs or billets. Molds may be circular, square, or rectangular in shape, with walls of various thickness. Some molds are of larger cross section at the bottom, other are larger at the top.
Iron	Primarily the name of a metallic element. In the steel industry, iron is the name of the product of a blast furnace containing 92 to 94% iron, the product made by the reduction of iron ore. Iron in the steel mill sense is impure and contains up to 4% dissolved carbon along with other impurities.
Iron Ore	The raw material from which iron is made. It is primarily iron oxide with impurities such as silica.
Iron Scrap	Blast furnace metal or other iron which may be salvaged before remelting in a blast furnace or in a steelmaking furnace.

Killed Steel Steel deoxidized with a strong deoxidizing agent such as silicon or aluminum in order to reduce the oxygen content to a minimum so that no reaction occurs between carbon and oxygen during solidification.

Kish A graphite formed on hot metal following tapping.

Ladle A large vessel into which molten metal or molten slag is received and handled. Molten metal may be transported short distances in a ladle.

Ladle Metallurgy A secondary step in the steelmaking process often performed in a ladle after the initial refining process in a primary furnace (BOF, EAF) is complete. Ladle metallurgy is conducted for one or more of the following purposes: control of gasses in the steel; remove sulfur beyond that removed in primary steelmaking; remove undesirable non-metallics; inclusion morphology; and, to change mechanical properties.

Lap A surface defect appearing as a seam caused from folding over fins or sharp corners during hot rolling and then rolling or forging, but not welding, them into the surface.

Lap Weld A term applied to a weld formed by lapping two pieces of metal and then pressing or hammering, and applied particularly to the longitudinal joint produced by a welding process for tubes or pipe, in which the edges of the skelp are beveled or scarfed so that when they are over-lapped they can be welded together.

Larry Car Movable device located on top of a coke battery for receiving and charging predetermined amounts of screened coal to coke ovens through charging holes.

Light Oil A clear yellow-brown oil with a specific gravity of about 0.889. It contains varying amounts of coal-gas products with boiling points from about 40°C to 200°C and from which benzene, toluene, xylene, and solvent naphthas are recovered.

Lime Calcium oxide (CaO), produced by burning limestone, principally comprising calcium carbonate ($CaCO_3$), in a lime kiln. Lime is used as a flux (slagging agent) in basic oxygen furnace steelmaking; limestone is used as a flux in blast furnaces for production of molten iron (hot metal).

Lime Boil	The fixed leg of the ammonia still to which milk of lime is added to decompose ammonium salts; the liberated ammonia is steam distilled and returned to the gas stream.
Liming	Application of lime to pickled rod produced in the wire industry for protection against corrosion and as a lubricant for cold drawing.
Machining	In general, the cutting away of the surface of a metal by means of power driven machinery. Specifically, a method of conditioning steel by machining the surface.
Malleability	The property that determines the ease of deforming a metal when the metal is subjected to rolling or hammering. The more malleable metals can be hammered or rolled into thin sheet more easily than others.
Mandrel	A metal bar around which other metal may be cast, bent, formed, or shaped.
Meltdown	The melting of the scrap and other solid metallic elements of the charge.
Mill Edge	Normal rounded edge produced in hot rolling. Does not conform to any standard radius. This replaces the old term, band edge.
Mill Finish	A surface finish produced on sheet and plate, characteristic of the ground finish on the rolls used in fabrication.
Mill Length	Those lengths which can be most economically handled by the mill. Upper and lower limits are set by equipment limitations in the mill.
Mill Scale	The iron oxide scale which breaks off of heated steel as it passes through a rolling mill. The outside of the piece of steel is generally completely coated with scale as a result of being heated in an oxidizing atmosphere.
Mold	A form or cavity into which molten metal is poured to produce a desired shape. See ingot molds.
Molten Metal Period	The period of time during the electric arc furnace steelmaking cycle when fluxes are added to furnace molten bath for the purpose of slag formation.

Molybdenum A special alloying element commonly used to increase hardenability of steel. Molybdenum is sometimes added to stainless steels to enhance corrosion resistance to certain chemicals.

Molybdenum Oxide A commercial compound of molybdenum (MoO_3) which is used as a finishing agent in making molybdenum steels.

Nickel A metallic element used in some alloy steels.

Nonrecovery Cokemaking Production of coke from coal with no recovery of coal by-products and by-product chemicals that are recovered with by-product cokemaking (e.g., coal tars, crude light oil, ammonia and/or ammonia compounds, naphthalene, sodium phenolate). In the nonrecovery cokemaking process, coking occurs in horizontal, refractory-lined ovens. Volatile components of the coal are consumed in the process.

Non-Standard Steel A steel is classified as non-standard when the chemical composition or mechanical properties specified do not coincide with or encompass the ranges of limits of a standard steel (AISI or ASTM), or when restricted ranges or limits are outside the ranges or limits of a standard steel.

Normalize The normalizing process which is commonly applied to steel articles of heavy section consists of: heating to a temperature about 100°F above the critical range and cooling in still air.

Off Size Rolled steel, too light or too heavy to meet requirements.

Oiled Application of a suitable oil to final product to resist corrosion. Where surface quality is a consideration, it is also desirable in reducing friction scratches that may develop in transit. The oil coating is not intended to serve as a lubricant for subsequent fabrication.

Open Hearth Furnace A furnace for melting metal, in which the bath is heated by the convection of hot gases over the surface of the metal and by radiation from the roof.

Open Plate Panel Hood A 4.5 meter to 6 meter square, rectangular, or circular cross sectional shaped conduit, open at both ends, which is used in the BOF steelmaking process for the combustion and conveyance of hot gases, fumes, etc., generated in the BOF, to the waste gas collection system.

Ore A mineral from which the metal can be extracted.

Ore Boil The generation of carbon monoxide by the oxidation of carbon.

Ovals A hot rolled carbon steel bar product which is oval in cross section.

Overfill A defect in a rolled bar or other section which is an overfullness on some part of the surface. Among the causes are worn rolls and extrusion into the clearance of the rolls.

Oxide Oxides of iron, chiefly: FeO, Fe_3O_4, Fe_2O_3. Many mixtures of these oxides exist which form on the surface of steel at different temperatures and give the steel different colors, such as yellow, brown, purple, blue, and red. Oxides must be thoroughly removed from steels to be coated with tin, zinc, or other metals.

Oxidize A chemical treatment which increases the positive valences of a substance. In a limited sense, adding oxygen to a substance, as in oxidizing C to CO, CO to CO_2, Si to SiO_2, Mn to MnO.

Oxidizing Agent A substance added to a mixture for the purpose of oxidizing some constituents. For example, iron ore (Fe_4O_3) was used in an open hearth furnace to furnish oxygen for the removal of Si, Mn, P, and C, by converting them to SiO_2, MnO, P_2O_5 and CO.

Oxidizing Slags Fluxing agents that are used to remove certain oxides such as silicon dioxide, manganese oxide, phosphorus pentoxide, and iron oxide from the hot metal.

Pass (1) Movement of a piece of steel through a stand of rolls. (2) The open space between grooved rolls through which the steel is processed.

Passivation Chemical treatment of hot dip galvanized sheet with hexavalent chromium compounds to prevent humid- or wet-storage staining.

Patenting In wire making, a heat treatment applied to medium carbon or high-carbon steel before the drawing of wire or between drafts. This process consists of heating the product in air or in a bath of molten lead or salt maintained at a temperature appropriate to the carbon content of the steel and to the properties required of the finished product.

Pelletizing The processing of dust from the steel furnaces into a pellet of uniform size and weight for recycle.

Phenols (4AAP) The value obtained by the method specified in 40 CFR Part 136.3. Phenols (4AAP) is a non-specific measure of phenolic compounds present in steel industry wastewaters that respond to the analytical test conditions.

Pickle Chemical or electrochemical removal of surface oxides.

Pig An ingot of virgin or secondary metal to be remelted for use.

Pig Iron Impure iron cast into the form of small blocks that weigh about 30 kg. each. The blocks are called pigs.

Piling A form of rolled structural shape of two types: sheet piling and bearing piling. The three forms of sheet pile - straight, arch type, and zee - are used for construction of docks, breakwaters, coffer dams, etc. Bearing piles, which range from 14 in. to 8 in. in depth, are heavy, wide flange sections used for foundation and similar applications.

Pinch Pass A pass of sheet through rolls that are set to give a very light reduction.

Pinch Rolls Rolls used to regulate the speed of discharge of cast product from the molds of continuous casting machines.

Pitch Distillate from tar.

Plain Carbon Scrap Scrap steel with less than: 1.65% manganese, 0.60% silicon, 0.60% copper, or any other alloying element added for a special alloying effect.

Plate Carbon steel plates comprise that group of flat rolled finished steel products within the following size limitation:

0.180 in. or thicker, over 48 in. wide;
0.230 in. or thicker, over 6 in. wide;
7.53 lb/sq ft or heavier, over 48 in. wide;
9.62 lb/sq ft or heavier, over 6 in. wide

Pouring The transfer of molten metal from the ladle into ingot molds or other types of molds; for example, in castings.

Preheating (1) A general term used to describe heating applied as a preliminary to some further thermal or mechanical treatment. (2) A term applied specifically to steel to describe a process in which the steel is heated slowly and uniformly to a temperature below the hardening temperature and is then transferred to a furnace in which the temperature is substantially above the preheating temperature.

Press Forging The forging process in which metal stock is formed between dies, usually by hydraulic pressure. Press forging is an operation that employs a single, slow stroke. Compare with hammer forging.

Primary Scale Oxide of iron (Fe_3O_4) which is formed while the steel is being heated.

Primes Metal products such as sheet and plate, of the highest quality and free from visible surface defects.

Process Annealing In the sheet and wire industries, a process by which ferrous alloy is heated to a temperature close to, but below, the lower limit of the transformation range and is subsequently cooled. This process is applied in order to soften the alloy for further cold working.

Quality Refers to the suitability of the steel for the purpose or purposes for which it is intended.

Quench Hardening A process of hardening a ferrous alloy of suitable composition by heating within or above the transformation range and cooling at a rate sufficient to increase the hardness substantially. The process usually involves the formation of martensite.

Quench Tower A station at which the incandescent coke in the cokecar is sprayed with water to prevent further combustion. Quenching of coke requires about 500 gallons of water per ton of coke.

Quenching A process of rapid cooling from an elevated temperature by contact with liquids, gases, or solids.

Quenching Crack A fracture resulting from thermal stresses induced during rapid cooling or quenching of steels. Frequently encountered in alloys that have been overheated and liquidated and are thus "hot short."

Recuperator A piece of equipment for recovering heat from hot, spent gases and using it for the preheating of incoming fuel or air. Incoming materials pass through pipes surrounded by a chamber through which the outgoing gases pass.

Reducing Slag Used in the EAF following the slagging off of an oxidizing slag to minimize the loss of alloys by oxidation.

Refining Oxidation cycle for transforming hot metal (iron) and other metallics into steel by removing elements present, such as silicon, phosphorus, manganese, and carbon.

Refractory Ideally, any substance which is infusible at the highest temperature it may be required to withstand in service. A perfect refractory, which does not exist at present, would be one which: (1) would not fuse or soften, (2) would not crumble or crack, (3) its contraction and expansion would be the minimum, (4) would not conduct heat, (5) would be impermeable to high temperature gases and liquids, (6) would resist mechanical abrasion, and (7) would not react chemically with substances in contact with it.

Rod Mill (1) A mill for fine grinding, somewhat similar to the ball mill, but employing long steel rods instead of balls as the grinding medium. (2) A mill for rolling metal rod.

Roll Forming (1) An operation used in forming sheet. Strips of sheet are passed between rolls of definite settings that bend the sheet progressively into structural members of various contours, sometimes called "molded sections." (2) A process of coiling sheet into open cylinders.

Roll Scale Oxide of iron which forms on the surface of steel while it is being heated and rolled. Much of the scale is cracked and loosened during the rolling operation and may fall off the piece naturally or be blown off by high-pressure water sprays or by other means.

Roll Table A conveyor-type table surface that contains a series of small rolls over which metal products pass during processing.

Roughing Stand The rolls used for breaking down the ingot, billet, or slab in the preliminary rolling of metal products.

Round Cornered Squares A bar product square in cross sections with rounded corners with size ranges 3/8 in. to 8 in., inclusive.

Runner A channel through which molten metal or slag is passed from one receptacle to another; in a casting mold, the portion of the gate assembly that connects the downgate or sprue with the casting.

Runout Escape of molten metal from a furnace, mold, or melting crucible.

Runout Table Area of a hot strip mill located after the finishing stands and before the coilers where laminar-flow cooling is applied to the strip; generally, for any hot forming mill, the area of the mill downstream of the last stand of work rolls; for continuous casters, the area downstream of the torch cut-off.

Scale An oxide of iron which forms on the surface of hot steel. Sometimes forms in large sheets which fall off when the steel is rolled.

Scarfing Cutting surface areas of metal objects, ordinarily by using a gas torch. The operation permits surface defects to be cut from ingots, billets, slabs, or the edges of plate that are to be beveled for butt welding.

Scrap Iron or steel discard, or cuttings, or junk metal, which can be reprocessed.

Secondary Scale Oxide of iron which is formed on hot steel while it is being rolled or forged.

Self-Hardening Steel A steel containing sufficient carbon or alloying element or both, to form martensite either through air hardening or, as in welding and induction hardening, through rapid removal of heat from a locally heated portion by conduction into the surrounding cold metal.

Semi-Finished Steel Steel in the form of ingots, blooms, billets, or slabs for forging or rolling into a finished product.

Semi-Killed Steel Steel incompletely deoxidized, to permit evolution of sufficient carbon monoxide to offset solidification shrinkage.

Shake-Out The operation of removing castings from their molds.

Shear In a steel mill, a machine for cutting steel products. Steel shears may be classified: as to kind of drive - hydraulic and electric; as to the work done - cropping, squaring, slab, bloom, billet, bar shears; as to type of mechanism - rotary, rocking, gate, guillotine, alligator shears; as to movement of work while shearing - flying shears.

Shot Blasting Abrasive grit blasting of steel to remove scale; used in place of or in combination with acid pickling.

Silico-Manganese An alloy containing silicon and manganese. In the open hearth process, it was used as a deoxidizer in the furnace and for the introduction of manganese and silicon into steel.

Sinter In blast furnace usage, lumpy material which has been prepared from flue dust, other iron-bearing materials, lime, and coke breeze. The dust is agglomerated by heating it to a high temperature. Sinter contains valuable amounts of combined iron.

Skelp A plate of steel or wrought iron from which pipe or tubing is made by rolling the skelp into shape longitudinally and welding or riveting the edges together.

Skin A thin surface layer that is different from the main mass of a metal object, in composition, structure, or other characteristics.

Slab A semifinished block of steel cut from a rolled ingot or manufactured on a continuous slab caster, with its width at least twice its thickness. It differs from a bloom which is square or nearly so. Currently, most slabs are produced with continuous casters as opposed to slabbing on blooming mills. Slabs are the product of a slabbing mill or a blooming mill.

Slab Shear A shear for cutting a cast slab to desired lengths. This shear also cuts off the discard or crop.

Slabbing Mill A mill which rolls ingots into slab shapes.

Slag Vitrified mineral waste removed in the reduction of metals from their ores. The principal components of blast furnace slag are oxides of silica and alumina originating chiefly with the iron-bearing materials and lime and magnesia originating with the flux. The major components of steelmaking slags are calcium silicates, lime-iron compounds and lesser amounts of free lime and magnesia. Usually, slags consist of combinations of acid oxides with basic oxides, and neutral oxides are added to aid fusibility.

Slag Top A variation of the hot top.

Soak	To hold an ingot, slab, bloom, billet, or other piece of steel in a hot chamber or pit to secure uniform temperature throughout. Freshly stripped ingots are hottest in the interior, whereas a cold object which is being heated is hottest at the surface. The term is used in connection with heating of steel whether for forging or rolling or for heat treatment.
Soaking Pit	A furnace or pit for the heating of ingots of steel to make their temperature uniform throughout.
Spark Box	A solids and water collection zone in a BOF hood.
Spiegeleisen (Also Spiegel)	A pig iron containing 15 to 30% manganese and 4.5 to 6.5% carbon.
Sponge Iron	The material produced by the reduction of iron oxide with carbon, without melting.
Stainless Steel	(1) A tradename given to alloy steel that is corrosion and heat resistant. The chief alloying elements are chromium, nickel, and silicon in various combinations with a possible small percentage of titanium, vanadium, etc. (2) by AISI definition, a steel is called "stainless" when it contains 10% or more chromium.
Steel	Refined iron. Typical blast furnace iron has the following composition: Carbon, 3 to 4.5%, Silicon, 1 to 3%; Sulfur, 0.04 to 0.2%; Phosphorus, 0.1 to 1.0%; Manganese, 0.2 to 2.0%. The refining process (steelmaking) reduces the concentration of these elements in the metal. A common steel, 1020, has the following composition: Carbon, 0.18 to 0.23%; Manganese, 0.3 to 0.6%; Phosphorus, less than 0.04%; Sulfur, less than 0.05%.
Steel Ladle	A vessel for receiving and handling liquid steel. It is made with a steel shell and lined with refractories.
Stools	Flat cast iron plates upon which the ingot molds are seated.
Stoves	Large refractory filled vessels in which the air to be blown into the bottom of a blast furnace is preheated.
Strand	A term applied to each continuous casting mold and its associated mechanical equipment.

Stretcher Flattening A process for removing bow and warpage from sheet by applying a uniform tension at the ends so that the piece is elongated to a definite amount of permanent set.

Strip, Hot Rolled Carbon Steel Flat, hot rolled carbon steel produced in coils or in cut lengths is classified as hot rolled carbon steel strip when the product is within the following size limitations:

Width	Thickness
up to 3-1/2 in. incl.	0.0255 to 0.2030 in. incl.
over 3-1/2 to 6 in. incl.	0.0344 to 0.2030 in. incl.
over 6 to 12 in. incl.	0.0568 to 0.2299 in. incl.

Support Rolls Rolls used in the continuous casting machine casting strand for keeping cast products aligned.

Tandem Mill A mill with a number of stands in succession.

Tap Hole A hole approximately fifteen (15) centimeters in diameter located in the hearth brickwork of the furnace that permits flow of the molten steel to the ladle.

Tap to Tap Time Period of time after a heat is poured and the other necessary cycles are performed to produce another heat for pouring.

Tapping Process of opening a taphole in a blast furnace to remove hot metal and slag; process of pouring molten steel from a steelmaking furnace into a receiving ladle for transfer to a ladle metallurgy station or continuous caster, or into a teeming ladle for pouring into ingot molds.

Tar The organic matter separated by condensation from coke oven gas in the collector mains. It is a black, viscous liquid, a little heavier than water. From it the following general classes of compounds may be recovered: pyrites, tar acids, naphthalene, creosote oil, and pitch.

Teeming Pouring or casting of molten steel from a ladle into cast iron ingot molds of various dimensions for cooling and solidification of the steel.

Temper A condition produced in a metal or alloy by mechanical or thermal treatment, and having characteristic structure and mechanical properties. A given alloy may be in the fully softened or annealed temper, or it may be cold worked to the hard temper, or further to spring temper. Intermediate tempers produced by cold working (rolling or drawing) are called "quarter-hard", "half-hard" and, "three-quarters hard", and are determined by the amount of cold reduction and the resulting tensile properties. In addition to the annealed temper, conditions produced by thermal treatment are the solution heat treated temper and the heat treated and artificially aged temper. Other tempers involve a combination of mechanical and thermal treatments and include that temper produced by cold working after heat treating, and that produced by artificial aging of alloys that are as-cast, as-extruded, as-forged and heat treated, and worked.

Temper Rolling Relatively light cold rolling process (1 to 4% thickness reduction) performed to improve flatness, alter the mechanical properties of the steel, and to minimize surface disturbances. Temper mills are usually single-stand mills.

Tempering A process of reheating quench-hardened or normalized steel to a temperature below the transformation range, and then cooling at any rate desired.

Tensile Strength The value obtained by dividing the maximum load observed during tensile straining until breakage occurs by the specimen cross-sectional area before straining. Also called "ultimate strength".

Terneplate Steel sheet, hot dip coated with terne metal (10-15% tin; 85-90% lead).

Three-High Mill A stand which has three rolls, one above the other. The steel which is being rolled passes one way between the bottom and middle rolls, and the other way between the middle and top rolls.

Tinplate A mild steel of low carbon content bearing a coating of commercially pure tin. Two manufacturing processes are currently used, hot dipped and electrolytic tinning lines.

Titanium A metal which is commonly added to chrome-nickel stainless steel to improve its welding properties. So used, it is called a "stabilizer" or is said to prevent "carbide precipitation." The amount of titanium commonly used for this purpose is 5 to 7 times the carbon content.

Train of Stands In rolling mill construction, those stands of rolls which are placed side by side (i.e., so that the rolls of the different stands come end to end so that one engine or motor can drive them). Contrast this with strands in tandem.

Tramp Oils Waste oils and greases from lubricating and other oil- or grease-containing systems.

Tundish A refractory-lined vessel located between the ladle and the continuous caster. Molten steel is tapped from the ladle to the tundish for the purpose of providing a stable flow of metal into the caster by providing a constant ferrostatic head.

Tungsten A metal which is sometimes added to steel to make tool steel.

Tuyeres Water cooled openings located around the circumference of a blast furnace at the top of the hearth through which the hot blast enters the furnace.

Two-High Mill A stand having only two rolls. Some two-high mills are reversing with screw-downs to adjust the rolls; others are one way only and may or may not have screw-downs for roll adjustment and may or may not be a part of a continuous mill.

Universal Plate Mill A mill for rolling steel plates which has vertical as well as horizontal rolls so that its product has rolled edges.

Upsetting (1) A metal working operation similar to forging. (2) The process of axial flow under axial compression of metal, as in forming heads on rivets by flattening the end of wire.

Vacuum Degassing A process for removing dissolved gases from liquid steel by subjecting it to a vacuum.

Venturi Scrubber A wet type collector that uses the throat for intermixing of the dust and water particles. The intermixing is accomplished by rapid contraction and expansion of the air stream and a high degree of turbulence.

Wash Oil A petroleum solvent used as an extractant for by-product recovery in the coke plant.

Water Tube Hood Consists of steel tubes, four (4) centimeters to five (5) centimeters, laid parallel to each other and joined together by means of steel ribs continuously welded. This type of hood is used in the basic oxygen steelmaking process for the combustion and conveyance of hot gases to the waste gas collection system.

Wet Scrubbers Venturi or orifice plate units used to bring water into intimate contact with dirty gas for the purpose of its removal from the gas stream.

Windbox Device for drawing air through the sinter strand to enhance combustion and fusing of the iron-containing materials into a sintered product.

Wire Rod A semi-finished product from which wire is made. It is generally of circular cross section approximately 1/4 in. in diameter.

Work Rolls Nongrooved rolls which come into contact with the piece of steel (slab, plates, strip, or sheet) being rolled. In four-high mills, the rolls which stiffen or strengthen the work rolls are called back-up rolls. The drive spindles are connected with the work rolls.